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ABSTRACT

Literature concerned with the preservice preparation of elementary school teachers in science and science teaching methods, both research studies and program guidelines, was reviewed along with studies of the status of elementary school science teaching. Most reports reviewed concluded that the present teacher education programs are an inadequate preparation for teaching science in elementary schools since the science content is often limited and specialized, and few special methods courses are provided. Although a number of studies investigated the competencies needed by teachers of elementary school science, this question requires further study. Areas where research needs to be done are identified and a plea for careful design and analysis, so that results are widely applicable, is made. Fifty references are cited. (AL)



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An Analysis of Research

On Elementary Teacher Education Related to the Teaching of Science

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THE Educational Resources Information Center (ERIC) comprises a network of decentralized clearinghouses in various locations throughout the United States. Each center focuses on a specific area of education and organizes its own program of acquiring, abstracting, indexing, storing, retrieving, and evaluating significant materials in the individual fields of interest. The clearinghouse for science education is located at Ohio State University in Columbus, Ohio. Since July 1966, a limited number of documents selected and catalogued by each clearinghouse have been announced in the monthly publication of ERIC, *Research in Education*. The science education clearinghouse of ERIC is of particular interest to elementary teachers since it is designed to help teachers keep informed of new instructional techniques and materials. For further information about the center and its services, teachers are encouraged to write to the authors.

THE purpose of this article is to report to the profession an analysis of recent research related to the preparation of elementary school teachers to teach science. When a comparison is made with the number of studies of the education in science of elementary teachers with those studies dealing with the preparation of secondary school science teachers, it would appear that science educators have tended to concentrate more of their research efforts on the preparation of teachers for the secondary schools rather than attempting to identify and define problems involved in preparing elementary teachers to do a competent job of teaching science. This situation persists despite the continuing criticisms that many elementary teachers do an inadequate job of teaching science, and also that many are reluctant to teach science. If this situation is to be changed, attention should be given to such problems as finding methods for improving the science competencies of teachers, determining the optimal content background and types of experiences in science for elementary teachers, building more positive attitudes toward science on the part of elementary teachers, as well as continuing the investigations into the area of science content and experiences that should be part of the elementary school curriculum.

Certification and Requirements For Elementary Teachers

The problem of providing an adequate preservice preparation program in science for elementary teachers has been one of continuing concern to science educators. The recommendation that elementary teachers have at

least 20 hours in science was made in the 46th Yearbook of the National Society for the Study of Education, *Science Education in American Schools*, published in 1947. In 1963, the National Association of State Directors of Teacher Education and Certification (NASDTEC) and the American Association for the Advancement of Science (1)* published a set of guidelines for science and mathematics in the preparation program of elementary school teachers. This joint committee recommended that every elementary teacher be educated in the fundamental concepts of the biological sciences, the physical sciences, the earth sciences, and mathematics. The development, by colleges, of interdisciplinary courses to illustrate these fundamental concepts was also recommended.

If these recommendations have been acted upon, this action is not yet apparent in state certification requirements as reported by Woellner and Wood (49). There is wide variation among the states in so far as the amount of science which an elementary teacher must have for certification. According to their publication, some states do not specify the amount of credit hours in science needed for certification. Requirements which are specified range from 6 to 15 semester hours, on the average. (California requires a major or graduate work in a single subject, amounting to 24-28 semester hours.) In some states, the amount of science required for certification varies with that required as a part of the general education component of the teacher's undergraduate program. There is very little uniformity to be found. The number of hours required for certification serves to set the minimum standard for preparation, not the optimum.

Status of Elementary School Science Teaching

The publication and dissemination of these recommendations and guidelines appear to have had little effect on science teaching as evidenced by research studies in which the status of elementary science teaching has been investigated: Blackwood (5), Smith and Cooper (38), Piltz (31), Moorehead (29), Verrill (44).

Blackwood (5) conducted a survey, under the auspices of the U.S. Office of Education, of science teaching in the elementary schools as it was reflected in teaching practices. As a result of the information gained from the questionnaire sent to elementary schools during 1961-62, Blackwood found that a great variety of purposes, methods, and resources for teaching science existed. He also found that science in the elementary schools is not a subject required by law in most states.

However, science was taught in most of the elementary schools responding to Blackwood's survey. The most common pattern in the early grades was that of science integrated with other subjects. The frequency with which science was taught as a separate subject increased by grade in all school enrollment groups up

through grade 5. This tendency toward separation increased in grades 7 and 8. Science taught as (A) a separate subject and (B) as a separate and incidental subject were the most common patterns in the upper grades.

Historically, science in the elementary schools has been taught by the classroom teacher. This was still the situation in the majority of the schools responding to the questionnaire. The frequency of this pattern decreased with increasing grade level. In a large percentage of schools with enrollments of 400 to 800 students, special teachers teach science to seventh- and eighth-grade students. Some schools, especially those with larger enrollments, had special science teachers from fourth through eighth grades. Regardless of whether a specialist or the classroom teacher taught science, some type of consultant help was available in most schools. A variety of personnel served as consultants, ranging from general elementary supervisors to high school science teachers.

Schools were asked to rank 13 items considered as barriers to effective science teaching. "Lack of adequate consultant service" was ranked first. Blackwood found that science was taught by a classroom teacher without the help of an elementary science specialist in over 80 percent of the schools in grades 1 through 5 and in over 70 percent of the schools in grades 6 through 8.

"Lack of supplies and equipment," "inadequate room facilities," and "insufficient funds for purchasing needed supplies, equipment, and appropriate science reading materials" were ranked second, third, and fourth in importance. "Teachers do not have sufficient science knowledge" was ranked fifth as a barrier to effective science teaching.

Blackwood concluded that if the inadequacies, revealed through this survey, are to be corrected and the present programs of elementary science are to be improved, reassessment is necessary. Attention should be given to such factors as (A) class size, (B) number of minutes per week that science is taught, (C) developing a systematically planned curriculum in science, (D) the acquisition of adequate supplies and equipment, including library books and other supplementary books and materials, and (E) provision for consultant services, among others.

Smith and Cooper (38) conducted an investigation to determine the frequency of use of eight science teaching techniques by elementary teachers. They attempted to determine the significance of the relationship between the frequency of use of each technique and certain professional and personal characteristics of teachers. They found that teachers with the most formal study in science, in addition to the undergraduate degree, used all the techniques, except reading and discussion of the textbook, with significantly greater frequency than teachers with little or no additional formal study in science. Teachers with the most college training generally used techniques other than reading and

* See References.

discussion of the textbook with greater frequency than those with lesser amounts of college training. However, there was little difference in the frequency with which the two groups of teachers used pupil recording and reporting observations. The researchers concluded that more variety in techniques for teaching science may be expected with better preparation programs and more knowledgeable teachers in the field of science.

Piltz (31) conducted a study to determine what factors, in the opinion of classroom teachers, handicap the teaching of science in the elementary school. He also wished to determine what relationship, if any, existed between the aspirations of teachers and the difficulties they thought they faced. He found the teachers surveyed to be in general agreement concerning the factors limiting science teaching in the elementary school. The difficulties were of two types: (A) those which could be remedied if the teachers were to attain a better understanding of science and how to teach it, and (B) other difficulties over which the teachers had little or no control. Piltz found conflict concerning content emphasis. He speculated that this conflict arose from the variety of factors that determine the focus of what is taught: the teacher's individual interest and competency, pressure from administrators, pupil achievement, environmental conditions, and the teacher's perception of what is important in the curriculum and in the lives of boys and girls.

Piltz found that a majority of teachers participating in his study considered inadequate physical facilities to be the greatest of all obstacles to effective science teaching. Another obstacle was that of lack of proper materials, equipment, and resources. He also found that some teachers lacked confidence in teaching science and that the majority were weak in the methodology of science teaching. The principals surveyed expressed the opinion that lack of training, of teacher interest, and of time and materials limited science teaching. Few, however, appeared to be doing anything to improve the situation.

Preservice Preparation in Science For Elementary Teachers

Apparently elementary teachers are frequently handicapped in teaching science effectively by conditions existing in many public schools. They may also be handicapped by the preservice preparation they receive. A number of studies related directly or primarily to the problem of preservice preparation in science for grade teachers are: Gant (19), Banks (3), Moorehead (29), Hardin (22), Eaton (15), Service (35), Kisner (24), Chamberlain (10), Esget (17), Bryant (7), Weaver (46), Lerner (26), Gaides (18), Gega (20), Michals (28), Eccles (16), Victor (45), Verrill (44), Cheney (11), Hines (23), Soy (39), Oshima (32).

Banks (3) conducted a study to determine what curriculum arrangements and classroom practices were employed at various teacher education institutions to meet

the needs of elementary science teachers. He inferred that science educators may be instilling an "isolationist posture" in preservice elementary teachers by not preparing them to utilize the services of science supervisors and consultants, and also by not emphasizing the possibilities inherent in such cooperative ventures as team teaching. Banks found inadequacies in the present organization of the teacher education program. The fact that science in the elementary school should be an integral part of the curriculum is not stressed. The preservice program for elementary teachers, according to Banks' data, also appeared to isolate practical experience, the study of educational psychology, and child growth from science teaching methodology. Another apparent weakness of many science education courses for elementary teachers was that preservice teachers were not involved in a sufficient variety of meaningful situations. Many courses did not appear to be designed to develop, in the preservice teacher, any depth of understanding of why science should be included in the elementary curriculum. Banks theorized that this aspect might have been neglected because the science educators were preoccupied with attempting to convince the preservice teachers that science is not so abstract and incomprehensible as they might have thought.

Gant (19), in a study made from 1957 to 1959, attempted to determine the experiences that elementary student teachers had in science programs in off-campus centers in New York. He concluded that too few elementary student teachers appeared to have problem-solving experiences in science teaching in off-campus cooperating schools, that there was insufficient use of community resources in the science program, that few science consultants were available to help elementary teachers, and that there was a definite lack of experience with such evaluation techniques as achievement and standardized test results, individual interviews with students, and pupil self-evaluation.

Gant suggested that a thorough appraisal of several possible approaches to science instruction be an integral part of the methods and materials course in elementary school science. Responses from the student teachers involved in this study seemed to indicate that the teaching experience would have been more satisfactory if they had had more instructional materials, more guidance in science teaching experiences, and more opportunity for participation in classroom science activities.

Verrill (44), as a part of a study designed to survey the preparation of general elementary teachers to teach science from 1870 to 1961, studied the teacher preparation programs in colleges and universities in a six-state area. He found that few schools had science subject-matter courses especially designed for elementary teachers. Only 19 of the 133 schools surveyed offered survey courses. The number of preservice elementary teachers who obtained their science subject-matter background as a part of the general education requirement was more than double that of any other one particular arrangement.

Chamberlain (10) also investigated the preservice education of elementary school science teachers. As a part of his research, he obtained information from inservice elementary teachers. When these individuals evaluated their college science courses, they found the basic courses in all sciences to be of value as well as courses in science education. They felt that, in preservice programs, there was a lack of qualified faculty to handle courses in elementary school science. Their replies seem to support the assumption that if teachers are adequately prepared in science, their problems related to actual teaching are fewer. Many respondents felt that additional training in science would be desirable, but more teachers were concerned with physical problems in the schools, such as lack of space and equipment, which they considered handicaps to effective teaching.

Hardin (22) surveyed the science preparation of preservice elementary teachers at The University of Miami. After analyzing the results of the students' scores on a test designed to reveal competency in science, Hardin concluded that preservice teachers are inadequately prepared. Women students showed greater inadequacy than men students; prospective primary teachers indicated more inadequacy than prospective intermediate teachers. The degree of inadequacy of preparation was revealed to be substantially the same for all five major areas of science. Hardin also concluded that laboratory experiences in addition to the completion of a course in science content and methods were significantly related to competency in science, as evaluated by the instrument used in the investigation.

Service (35) investigated the preservice education in science of elementary teachers at selected California teacher education institutions. He attempted to develop a proposed program of science preparation for elementary teachers. Service suggested that the science preparation program for preservice elementary school teachers should consist of (A) broad, survey-type courses in the biological, physical, and earth-space sciences with emphasis on concept formation, scientific principles, demonstrations and opportunities for practice in science inquiry and (B) courses affording opportunities for study in depth in specific areas, designed for the elementary school teacher.

Gega (20) asked 104 elementary teacher education students to list the things they liked most and disliked most about science courses in an attempt to determine if such information could be useful in improving preservice preparation for elementary teachers. He found that students objected to attempts to cover too much material, emphasis on memorization of unrelated details, tests on trivial objectives, and little or no application of material studied to every-day life, among other things. Gega concluded that, if the comments from the students were acted upon, the preservice courses would have objectives based on student performance, subject matter organized about relatively few generalizations, an emphasis on important social and practical applica-

tions of material studied, and would involve laboratory experiences. He suggested that these courses be taught by instructors with interests and training suitable for teaching an interdisciplinary course in science for non-majors.

Gega noted that a professional education course in elementary science should introduce students to basic knowledge and methods in several areas of science. Such a course should also include information on how science is organized in elementary schools, the strategies and tactics of science teaching, methods of evaluation, and methods to plan lessons that incorporate all these considerations.

Lerner (26) conducted a study to determine the status, trends, objectives, content, instructional procedures, and problems related to the methods course in elementary school science in selected four-year institutions of higher education. She found that 78 percent of the 291 institutions she surveyed provided training in methods for elementary school science, although some institutions apparently had a multiple methods course for elementary teachers rather than one devoted solely to the teaching of science in the elementary school. The instructors surveyed reported three major problems: the poor science background of their students, lack of favorable facilities for laboratory work, and class enrollments which they considered too large for effective teaching conditions. One of the primary problems in the multiple methods course was the lack of time to teach methods for more than one content area in a single course.

Victor (45), operating on the premise that the assumption that elementary teachers were reluctant to teach science was a valid one, surveyed 106 teachers in one school system to determine why they were reluctant to teach science. He found that a lack of familiarity with science content and materials, due to an inadequate science background, was a major factor. Eleven of the teachers responding to Victor's questionnaire had had no science beyond general science in high school. However, 75 percent of those surveyed had two full years of college science. Victor found that those teachers with a background in college science spent more time teaching science and used demonstrations and experiments more often than did those teachers having fewer courses in science.

Hines (23) also conducted a study related to the assumed reluctance of elementary teachers to teach science. She attempted to determine possible relationships existing between this reluctance and nine different factors. She found that teachers were providing more time for science teaching, demonstration, and experimentation than one would expect from a review of the research. She also found that an inadequate science background is a definite factor influencing science teaching at the elementary school level. Hines concluded that the number of years of teaching experience, the grade level being taught, and the experience of having had a science methods course appeared to have little

effect on the teaching performance of the population involved in her study. The differences that occurred among groups appeared to be due primarily to the types of classroom teaching situations.

Eaton (15) surveyed elementary education students enrolled at the University of Texas to determine why few of them elected science as an area of subject-matter concentration. He found that the students received little guidance from the faculty although they received considerable discouragement from their peers in selecting an area of science. After observing teacher behavior and surveying prospective teacher attitudes, he concluded that students lacked insight into the application of a concentration in subject matter to the teaching act. Apparently they need help in perceiving the relationship between content and instruction.

Soy (39) also investigated the attitudes of prospective elementary teachers toward science as a field of specialty. She found that interest was a most important reason for choosing a subject field. She discovered that science received the fewest votes as a high school subject in which students had felt most successful. Science ranked fifth of the seven subject areas in which students felt prepared to teach, although it was ranked first among the subjects which the student teachers felt elementary students would like to study. Soy concluded that something must be done to give preservice elementary teachers more satisfying experiences in science.

Oshima (32) compared two methods of teaching a science methods course for prospective elementary teachers. He found that the two different methods used in the study, lecture-demonstration and individual investigation, produced no significant changes in attitudes toward science. However, the experimental group which had been conducting individual investigations did make significant gains in their confidence toward teaching science.

Cheney (11), in a study designed to increase the commitment of preservice elementary teachers to teaching science, found that the students involved had little inclination to become specialists in elementary science either before or after the teaching-learning experience. He found that the tendency of the students to deplore their weaknesses in science knowledge was not matched by efforts to remove deficiencies through self-study or extended laboratory investigations. The students did appear, however, to gain confidence in their ability to teach science.

The breadth and depth of science content background acquired by an elementary teacher appears dependent on a number of factors. One of these relates to the graduation requirements of the particular institution in which the preservice teacher is enrolled. The amount of science required in the general education component of a preservice teacher's preparation is limited. Often no provision is made for attaining a balance in the various fields of science. Another determining factor is that of the teacher's interest in and attitude toward science. Attitude development is, apparently, a long term

process. Attitudes, once established, are not likely to be changed as a result of the experiences which the preservice teachers have in one course of only one quarter or one semester's duration. The preservice teachers frequently take only one methods course which is a general one related to the various disciplines involved in the elementary curriculum. Again, time is too limited for provision of adequate experiences in science teaching methodology. A third factor is that of the guidance, or lack of it, which the individual receives in planning his program. The majority of the researchers whose studies are cited in this part of the paper appear to conclude that the present preparation programs are inadequate for teaching science, in an effective manner, in the elementary school.

Teacher Competence Research

Perhaps the teaching of science in the elementary school could be improved if science educators were to concentrate upon developing a set of competencies which elementary teachers should possess relative to the teaching of science rather than assuming that the completion of a certain number of credit hours of course work will produce teaching effectiveness in a classroom situation. A current interest in teacher education appears to be concerned with this approach to preservice education. A number of investigations were concentrated upon the determination and development of competencies in science that elementary school teachers should possess: Uselton (43), Uselton, Bledsoe, and Koelsche (42), Sharefkin (36, 37), Reed (33), Michals (28), Butts (8), Mattheis (27), Moyer (30a), Cunningham (13), Weigand (47), Senter (34), DiLorenzo and Halliwell (14), Bryant (7).

Michals (28) conducted an investigation relevant to the topic of teacher competence. He attempted to determine the desired objectives for the preparation of teachers for teaching elementary science, the kinds of experiences that would produce competent elementary teachers, and the kind of science education programs needed. He selected as desired competencies three of the six roles of the teacher formulated in a study by the California Teachers Association: the director of learning, the mediator of the culture, and a member of the profession. Course activities were considered for selection in terms of three criteria: (A) is the experience practical preparation for elementary science teaching? (B) is the experience related to the operational definition of objectives? and (C) can the experience be evaluated? Three courses were set up at two different institutions and evaluated on the basis of a rating scale and the results of an Elementary Science Education Test. Michals found that there was a higher level of student achievement in the general discussion and group activities class than in the lecture-demonstration class. The schedules of the two institutions were not identical. This resulted in one class, at one institution, meeting 40 times as compared with the 24 times that each of the other two classes met. Michals found, upon

analyzing the data, that approximately the same percent of students in the two experimental courses, at the two different institutions, achieved the objectives when an equal amount of time was available for each topic and the same method of presentation was used. However, when additional time was available, a higher percent of students achieved the objectives. It would appear that the amount of time needed to achieve the desired objectives needs to be investigated. The level of achievement of these objectives also needs to be assessed.

Sharefkin (36) investigated the science knowledge and competencies of students enrolled in a liberal arts college. She attempted to identify the relationship between the college science training of student teachers and the student teachers' appraisal of their need for, as well as the extent to which they believe they possess, science abilities. She considered such abilities as those related to (A) identifying and defining problems, (B) suggesting or screening hypotheses, (C) selecting validating procedures, including the design of experiments, (D) interpreting data and drawing conclusions, (E) evaluating critically claims and statements of others, and (F) reasoning quantitatively and symbolically. The majority of the students participating in the study were aware of their need for science abilities. They appeared to feel that they were strongest in the areas of identifying and defining problems and in interpreting data and drawing conclusions. Only 34.8 percent of those investigated thought they needed to be able to reason quantitatively. Sharefkin suggested that criteria are needed to help student teachers clarify their own conceptions of, as well as identification of, children's behaviors which exhibit the science abilities emphasized in the study. She inferred that the student teachers' major difficulties were related to evaluating their science teaching and implementing science objectives. She concluded that elementary school student teachers need to develop awareness of their limitations so that they can critically examine their approach to teaching science and can function constructively in professional growth and teaching competence.

Problem solving is another skill which it is assumed that teachers should possess. Butts (8) conducted a study with 21 college seniors in an elementary science teaching methods course in order to measure their problem solving behavior. He wanted to determine the possible relationship between the knowledge of scientific facts and principles and the problem-solving behavior of the students. He found that problem-solving behavior was not characterized by patterned thought in this study. He hypothesized that teachers need to be trained to (A) focus on their ability to use knowledge rather than on the accumulation of knowledge, (B) search for basic principles rather than to memorize facts, (C) critically analyze data rather than to accept scientific facts without qualification, and (D) generalize from basic principles and scientific applications.

Mattheis (27) investigated the effect on the competence of preservice teachers for teaching science pro-

duced by two different types of laboratory experiences. He was interested in competence as it was reflected in subject-matter achievement and interest in science. He tested the assumption that laboratory experiences in science are necessary if the preservice education of elementary school teachers is to be successfully accomplished. The experimental group used a science-project approach to laboratory work while the control group was taught by the conventional replication-verification method. Mattheis found that, with respect to knowledge of science, the project approach to laboratory experiences was more efficient for students who exhibited strong interest and a proficient knowledge of science. However, students who were not interested in and who did not know very much about science learned more science when they were in the control group. Students were divided in their preferences for the two approaches to laboratory work. Some suggested that the good points of both types of laboratory work be utilized to develop a suitable laboratory course for preservice elementary teachers.

Two studies, Moyer (30a) and Cunningham (13), were concerned with development of competence in question asking. Moyer observed and tape recorded 14 science lessons, in five different elementary schools, involving 12 teachers. He compiled a total of 2,500 questions. Moyer found that over 50 percent of the questions were initiated with WHAT, HOW, WHY, WHO, WHERE, WHICH, and WHEN. He did not, however, find any evidence of a question that required students to evaluate. Moyer found that teachers with undergraduate majors in a field other than education tended to ask more questions requiring the children to explain than did those who had majored in education. He inferred that teachers are not prepared to develop and use questions effectively, and that teachers tend to frame questions in such a way that their pupils are not truly stimulated to think about and develop adequate concepts.

Although many teacher educators emphasize the use of sound questions to encourage children to think and caution their students to avoid telling children everything, this advice does not appear to be followed. However, Moyer found that the teachers he interviewed reported they received almost no instruction or suggestion relative to the methods of developing and utilizing questions as a part of their preparation for teaching.

Cunningham (13) conducted a study to determine the effects of a method of instruction designed to improve the question-phrasing practices of prospective elementary teachers. Forty elementary education majors participated in the study. He found that the ability of the prospective elementary teachers to construct a greater proportion of effectively phrased questions could be improved by the techniques which he used. The students who participated in the study also learned to construct a greater proportion of divergent questions for their science teaching.

Weigand (47) investigated another facet of the ques-

tioning process. He wished to determine if the ability of prospective elementary school teachers to ascertain the relevancy or irrelevancy of children's questions in elementary school science could be improved. He also investigated the effects, if any, of the preservice teacher's content background and academic grade-point average on this ability. He found that prospective teachers could determine the degree of relevancy of children's science questions and that this ability could be improved. Academic ability did not prove to be a factor affecting the ability to analyze questions. On the basis of the data he collected, Weigand inferred that factors other than subject-matter content were important in analyzing the relevancy or irrelevancy of science questions of children.

Two research studies were concerned with the use of specialists to teach science in the elementary schools, Senter (34) and DiLorenzo and Halliwell (14). Senter investigated the level of science achievement of sixth-grade students as it was related to teacher factors such as age, teaching experience, concentration in science courses, and styles of teaching. Analysis of the data relative to certain science knowledge, understanding, and concepts held by the students did not reveal any significant differences in the test results between students from self-contained classrooms and those in departmentalized classroom situations.

DiLorenzo and Halliwell (14) investigated the science achievement of 258 sixth-grade children to compare the scores of those taught by regular classroom teachers with the scores of children taught by special science teachers. They found no true difference in achievement of the two groups for either boys or girls. They did, however, hypothesize that different results might have been obtained if their investigation had lasted longer than seven months. They also questioned the use of available standardized tests in science as being valid appraisals of the objectives of the newer science programs.

It might be assumed that the competencies needed by teachers in the primary grades would be different from those needed by upper elementary school teachers. Bryant (7) considered this possibility as a part of his investigation designed to determine the amount of attention given, in required science courses, to the science understandings considered important for children. He found no substantial evidence of any difference in training in the institutions studied. Only 3.7 percent of these institutions reported any differentiation in requirements. In general, the science training programs for elementary school teachers were the same for all grade levels. There was no evidence to indicate that those who plan the programs think that it should be otherwise. Bryant found discrepancies between what children are expected to learn in science and the science education of preservice teachers to prepare them to facilitate this learning. This would suggest that elementary science curricula of institutions preparing teachers should be critically examined.

The question of teacher competence requires further investigation. Definite objectives need to be defined and assessed. The degree of competence a preservice teacher can be expected to achieve as a result of courses and experiences gained during a period of undergraduate education needs to be ascertained. Research should be done to determine if primary teachers need a set of competencies different from those needed by upper-grade teachers. If a set of desired competencies can be formulated, further research will need to be done to determine the sequence of courses and experiences to be included in the preparation program in order to achieve these competencies.

Teacher Behaviors, Characteristics

A number of researchers were interested in investigating the variables of teacher behavior and characteristics as these related to effective science teaching in the elementary school: Reed (33), Wishart (48), Beringer (6), Taylor (40), Hardin (21), Uhlhorn (41), Coffey (12).

Wishart (48) conducted research to determine the relationship of selected teacher factors to the character and scope of the science teaching program in self-contained elementary school classrooms as evidenced in 48 elementary classrooms. He found a number of significant differences among teachers relative to their backgrounds and understandings of science. Considerable differences were revealed relative to science teaching practices. Teacher understanding of science and understanding of child development appeared to be significantly related to each other. Understanding in those areas appeared to be greatest for teachers with the least authoritarian tendencies.

Reed (33) conducted a study of the influence of teacher variables on student learning. He chose to investigate teacher warmth, teacher demand, and the teacher's utilization of intrinsic motivation. His learning criterion was the pupils' interest in science as measured by the Reed Science Interest Inventory. There appeared to be a positive correlation between the teacher's use of intrinsic motivation and pupil interest in science. There was also a positive and moderately strong correlation between teacher warmth and pupil science interest.

Reed found a strong tendency for teacher demand or the degree of expectations concerning the students' maintenance of high standards of performance on school tasks and the utilization of intrinsic motivation to exist in the same teacher. He found the variables of teacher demand and warmth to be independent. Reed inferred, from an analysis of his data, that moderate demand does not necessarily sacrifice such goals as science interest. He postulated that preservice teachers could learn to become skillful in the use of intrinsic motivation as a part of their preparation programs in science education. Warmth, however, is a characteristic less amenable to development through teacher education experiences.

Beringer (6) was interested in determining whether the recency of a teacher's preservice education was related to the teacher's ability to understand scientific facts. She was also interested in discovering if the grade level at which the teacher worked and the amount of physical and biological science background the teacher possessed were relevant to this ability. After analyzing the 290 returns from the *Scientific Fact Test for Elementary Teachers*, Beringer concluded that teachers who were trained 1 to 4 years ago had a better understanding of scientific fact than teachers who have been out of college for 25 years. She found that teachers in the upper-elementary grades have a better understanding of scientific fact than teachers in the lower-elementary grades. Teachers appeared to have a better understanding of the biological sciences than of the physical sciences. However, in every category there were great variations in the percentages of correct answers. Apparently there are gaps in teachers' understandings of scientific fact in all areas of science.

Taylor (40) analyzed the teachers' attitudes toward instructional materials in a programed learning situation in science and the relationship of these attitudes to pupil achievement. He worked with 16 fourth-grade teachers and 89 randomly selected pupils for a four and a half month period. He concluded that while teacher attitudes toward programed science materials do not contribute significantly to measured pupil attitudes toward these materials, there was evidence that teacher attitudes influenced potential pupil achievement. Teacher attitudes appeared to contribute 18 percent of the variance in pupil final achievement. The teachers' attitudes were significantly correlated with their responses to the instrument *How I Teach: Analysis of Teaching Practices*.

Hardin (21), in a study designed to investigate dimensions of pupils' science interest and of their involvement in classroom science experiences in selected fifth- and sixth-grade classes, found that pupils could distinguish various aspects of their classroom experiences. The pupils appeared to be keenly aware of the teacher-pupil relationships. These relationships were highly significant to pupils, with warm teacher-pupil relationships being an important component of an effective teaching-learning situation.

Uhlhorn, Boener, and Shimer (41) found the ability to establish rapport with children to be an important teacher characteristic. They conducted an investigation in conjunction with a pre-student teaching experience in science for elementary education students at Indiana State University. Two other characteristics that appeared to be important in determining the success of the lesson were the ability to use teaching aids and the depth and breadth of knowledge of the subject included in the lesson. The researchers felt that further investigation needs to be done before it can be concluded that these characteristics are vital to successful science teaching.

Coffey (12) investigated the verbal behavior of

teachers of the lower-elementary grades. He found significant differences between the pre-and post-tests of the experimental group, based on an analysis of interaction analysis data, relevant to their understanding of science and their attitudes toward science. He inferred that the procedures used in this study facilitated the teachers' perceptions of learner needs and strategies of teaching which enhance learner needs.

Use of New Media and Techniques In Teacher Education

Two investigations were reviewed which involved the use of some of the newer procedures in the education of elementary school teachers: Ashlock (2) and Kriebs (25). Ashlock (2) used micro-teaching in an off-campus methods course for elementary school teachers. Micro-teaching involves teaching a lesson of 5 to 20 minutes length to a class of 4 to 8 students. The students taught a 5-minute lesson, which included a demonstration, to four of their peers who served as pupils for the microclass. Ashlock and his students found that if the lesson objectives were not stated in terms of the desired pupil behavior, the teacher had difficulty in achieving instructional closure.

Kriebs (25) conducted a study to compare the effectiveness of two types of videotaped instruction for preparing elementary school teachers to teach science. She was interested in determining if preservice teachers who observed videotapes of elementary school children using scientific methods performed significantly better as science teachers than did those preservice teachers who observed videotapes of a traditional lecture-demonstration class not involving children. The students involved in the study were videotaped in a teaching situation before the experimental treatment began and were again videotaped at the end of the experimental treatment. Kriebs based her comparison on the results of a paper and pencil test as well as on direct observation of teaching performance. She found there was no significant change in the preservice teachers' classroom performances as a result of the experimental treatment. However, those students who had viewed the videotapes involving children tended to receive higher ratings on their classroom performance than those who had viewed the control videotapes. The preservice teachers who had viewed the control videotapes gained significantly more science knowledge over the same content than did those who had viewed the experimental videotapes involving children. It would appear that there is no one easy method to provide both science content and teaching methodology.

Summary and Recommendations

Research studies concerned with the preparation of teachers to teach science to elementary school children have been reviewed, as have guidelines for preparation programs. Studies which focused on the status of elementary school science teaching were also included in the review. Research related to inservice education

programs in science for elementary school teachers was not included in this article.

It might be inferred, from an analysis of these research reports, that elementary school science teaching is handicapped by deficiencies in both course content and teaching methodology in so far as teachers' backgrounds are concerned as well as by inadequate teaching conditions in the schools. Individuals desiring to teach at the elementary school level cannot be prepared as specialists in all of the subject-matter areas which they are called upon to teach in a self-contained classroom, at least within the present four-year preparation period. If the length of the preservice program is not to be extended, preparation in depth and breadth within a particular subject-matter area is limited. Students preparing to teach elementary school frequently take one general course in teaching methodology. Again, due to time limitations, they do not receive training and experiences in sufficient depth in all of the subject-matter areas. Frequently, students do not have the opportunity during their student teaching experience to teach all of the subjects included at that particular grade level. Elementary school teachers, because they lack familiarity with science content and materials, express reluctance to teach science. Research needs to be done to determine how the preservice program for elementary school teachers can be structured to provide as wide a range of experiences and instructional content in science as possible.

Current certification patterns appear to be based on courses completed rather than upon classroom performance. Are the concepts of *legally qualified* and *competent* teachers equivalent ones? More research should be conducted relevant to the problems of teacher competence. A publication entitled *Six Areas of Teacher Competence* (9) details six roles of the teacher: director of learning, counselor and guidance worker, mediator of the culture, link with the community, member of the school staff, and member of the profession. Are all of these of equal importance in the preparation of elementary teachers? The authors of this publication expect beginning teachers to possess minimum competence in each role. Is it possible that not all beginning teachers are aware of the fact that they are expected to function in these roles? Are preparation programs perpetuating the stereotype role of the teacher as a purveyor of information? Does current emphasis upon learning by discovery hold implications for the modification of any of these roles? Does an individual who thinks of himself as a *director* of instruction function in a manner calculated to develop students who are independent learners? More research needs to be done in science education at the elementary school level to show the relationship between preparatory programs and product outcomes.

Teaching involves interaction between the teacher and students. Research studies based on the investigation of teacher-pupil interaction in science need to be extended downward into the elementary school. Those

studies which have been done have been limited to observations of situations involving the teacher and the majority of the class. Elementary teachers work with individual students and with small groups to an even greater extent than do secondary school teachers. Research should be done to determine how science activities taking place during such sessions differ, if they do, from those times in which the teacher is involved in working with the entire group.

Few research studies have been done to lead to the development of any theory of instruction relative to science teaching, at either the elementary or the secondary school level. Would adequate research result in the development of a theory of teaching science that would differ from theories for teaching other subjects? Would it differ for different levels of maturity of the students? Would it differ if science were to be taught to elementary school children by a teacher specializing in science as opposed to the present classroom teacher who has been trained to function as a generalist?

Research needs to be done relevant to the ways in which elementary teachers handle the problem of individualization of science instruction and the ways in which they accommodate for individual differences of their students.

Within the last five to eight years new programs have been appearing in elementary school science. Are preservice teachers being prepared to do an effective job with these new courses and materials? Teachers have to implement programs which they did not help to originate. Both beginning and experienced teachers need to know what to do in terms of both content and instructional strategies, how to implement the strategies involved, and they also need to understand the underlying rationale of the program. Research should be done to determine the degree to which prospective elementary teachers are being prepared to make effective use of the new elementary science projects.

In addition to the development of new programs in elementary school science, elementary education is being affected by such developments as team teaching, the ungraded elementary school, programmed instruction, and new materials and media. Are prospective teachers being prepared to function in such a changing environment?

Barnard (4), in discussing Bruner's *The Process of Education*, says that Bruner's ideas imply "... all children should be able to find the cognitive aspect of science an intellectually stimulating experience." This implies that elementary school teachers need to help children learn how to learn and to structure the experiences so that the students can be led to discover concepts on their own. To accomplish this, the teachers should be individuals who have found the study of science to be a personally satisfying experience. Can the preservice program be restructured to accomplish this goal?

Science education is faced with unresolved issues in

the different areas described in this paper. Exact knowledge of these issues is essential for continued development of the education of science teachers, at both the elementary and the secondary school levels. Basic questions need to be asked and researchable problems identified. Areas for study should include those concerning the content and experiences to be provided in the preparatory programs, the relationship of the content and experiences to teacher behavior, and the relationship of resulting teacher behavior to the behavior of students in the classroom situation.

The investigations must be designed and carried out in such a manner that the data can be tabulated, analyzed, and interpreted so that the study is replicable, the findings generalizable, and capable of wide application. Obourn and Blackwood (30b) state that "The cultivation of basic research is just as important to the well-being and advancement of science education as it is to the advancement of science and technology. To deny this, as many do, is to consign science education to the uncertain pitfalls of unexamined theory, mere opinion, and every man's foregone conclusion."

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